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DEVELOPMENT OF MARINE FILTER CLEANER USING COMPRESSED AIR IN PACKAGE

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ABSTRACT

This study focuses on the development of a marine filter cleaning device using compressed air technology, specially designed for application within the confined spaces of a ship's engine room. The research aims to address the challenges of filter maintenance in tight and demanding marine environments by introducing an innovative solution that is compact, portable, efficient, and user-friendly. The development of this tool incorporates the use of high-quality materials such as acrylic, PVC, aluminum piping, and anti-slip rubber, combined with a high-pressure compressed air system to ensure a more effective cleaning process without damaging the original structure of the filter. Through a series of simulated experiments conducted in a controlled environment, the device has demonstrated its capability to significantly reduce cleaning time, improve the cleanliness level of filters, and optimize workspace utilization on board. The tool's performance reflects its potential to lower long- term maintenance costs and enhance the overall operational efficiency of marine vessels by minimizing downtime. This advancement not only brings economic benefits but also promotes operational reliability in maritime operations. Moreover, this innovation supports the national TVET (Technical and Vocational Education and Training) agenda by encouraging practical skills development and strengthening research and development (R&D) in the field of marine engineering. The project also provides a platform for applied learning, bridging theoretical knowledge with real-world technical challenges and fostering innovation among students and marine professionals. Overall, the findings of this research present a novel approach with the potential to revolutionize marine maintenance practices by making them more systematic, cost-effective, and sustainable. This solution is aligned with the evolving needs of the modern maritime industry, which demands increased efficiency, safety, and environmental responsibility. The success of this project highlights the importance of integrating engineering innovation with practical application, reinforcing the role of technology in advancing maritime maintenance standards.

1. Introduction

Marine engine rooms are critical compartments onboard ships that house essential propulsion and auxiliary machinery. These spaces are typically confined, crowded with complex mechanical and electrical systems, and subjected to high operational demands. Among the routine maintenance tasks required in such environments, filter cleaning stands out as a time- sensitive and operationally crucial activity. Filters such as fuel filters, lubricating oil filters, and air intake filters play a vital role in ensuring that machinery systems operate efficiently and without contamination. However, over time, these filters accumulate sludge, debris, and carbon deposits that compromise their functionality. Regular cleaning or replacement is therefore necessary to maintain optimal engine performance, reduce fuel consumption, and prevent costly breakdowns.

Traditional filter cleaning methods employed on board ships generally include manual brushing, soaking in cleaning chemicals, or using hot pressurized water. While effective to a certain extent, these methods come with several limitations:

a) Labour Intensive: Crew members must manually dismantle, clean, and reassemble components, which is both time-consuming and physically demanding.
b) Space Constraints: Engine rooms offer limited space for maintenance activities, making it difficult to perform cleaning tasks safely and efficiently.
c) Environmental & Safety Risks: Use of chemicals or hot water increases the risk of burns, chemical exposure, and pollution.
d) Extended Downtime: Traditional cleaning often requires machinery shutdowns, causing delays in vessel operations and increasing operational costs.

In response to these challenges, this research focuses on the design and development of an innovative marine filter cleaning device powered by compressed air. The proposed solution is compact, portable, user-friendly, and specifically engineered for operation in confined marine spaces. The system uses high-pressure compressed air to dislodge contaminants from filters without dismantling major components or using hazardous chemicals. This not only improves cleaning efficiency but also enhances onboard safety and reduces overall maintenance time. The innovation also aligns with the objectives of Technical and Vocational Education and Training (TVET) by integrating practical engineering design, human factor considerations, and sustainability principles. This project ultimately aims to deliver a cost-effective and reliable solution to the long-standing issue of filter maintenance aboard ships, with potential applications across commercial, naval, and educational marine sectors.

2. Methodology

This research adopts a design-based engineering methodology to develop, test, and evaluate a portable marine filter cleaner powered by compressed air. The methodology is structured into six key phases: design conceptualization, material selection, fabrication, system integration, performance testing, and comparative evaluation. Each phase is outlined in detail below.

2.1 Design Conceptualization

The initial phase involved identifying the operational limitations of existing filter cleaning methods onboard ships. A requirement analysis was conducted based on interviews with marine engineers, maintenance crew, and ship cadets. Key design goals were formulated:

a) Compact and lightweight structure for easy mobility in confined spaces.
b) Non-electric system (to avoid explosion risk in engine rooms).
c) Minimal disassembly required during filter cleaning.
d) Durable and marine-grade components.

A conceptual sketch and flow diagram of the compressed air cleaner was produced using CAD software (*AutoCAD / SolidWorks*), focusing on ergonomic grip, stability, and nozzle efficiency.

2.2 Material Selection and Fabrication

To ensure durability, safety, and cost-effectiveness, the following materials were selected:

Table 1. Marine filter cleaner components

Component	Material Used	Reason for Selection
Main Frame	Clear Acrylic Sheet	Lightweight, visible operation, corrosion-resistant
Air Supply Channels	PVC Piping	Pressure resistant, non-corrosive
Support Base	Anti-slip Rubber	Stability during operation
Nozzle & Connectors	Aluminum Alloy	Strong, rust-resistant, lightweight
Fasteners & Valves	Stainless Steel	Marine-grade strength

All components were assembled manually using marine workshop tools at the Centre of Technology in Marine Engineering (CTME), Politeknik Ungku Omar.

2.3 System Integration

The compressed air system was designed to operate at 6–8 bar (90–115 psi)—an optimal range for dislodging particles from filter mesh surfaces without damaging the structure.

Key features of the system include:

a) Trigger-controlled nozzle: For directional airflow.
b) Flexible hose with coupling: To connect to onboard air compressors.
c) Filter stand: To stabilize filters during cleaning.

2.4 Prototype Testing Setup

Testing was conducted in a simulated engine room environment within the marine engineering laboratory. Five types of standard marine filters (lubricating oil, fuel oil, sea water, bilge water, and air intake) were cleaned using:

a) Traditional Method: Manual brushing and chemical soaking.
b) Innovative Method: Compressed air-powered cleaner.

Each method was repeated three times per filter type to ensure consistent results. The filters were weighed, inspected under microscope, and visually documented pre-and post-cleaning.

2.5 Parameters Measured

The performance of both methods was assessed using the following criteria:

Table 2. Experiments parameters

Parameter	Measurement Approach
Cleaning Time	Stopwatch-based measurement (in minutes)
Cleanliness Level	Visual score (1–5 scale) + weight difference (g)
Safety	Incident count + ergonomic risk observations
Ease of Use	User survey (Likert scale 1–5)
User Satisfaction	Feedback from marine engineers and cadets

2.6 Data Collection and Analysis

a) Quantitative data (time, weight, scores) were tabulated using Microsoft Excel and analyzed using SPSS for average values, standard deviation, and performance trends.
b) Qualitative feedback was coded into themes (e.g., “ease of grip,” “noise,” “effectiveness”) to identify design improvement areas.

2.7 Project Timeline (Gantt Chart)

The overall project duration was scheduled from 5 February 2024 to 24 May 2024, covering eight distinct phases from design to final presentation. The detailed planning and execution timeline is illustrated in the Gantt chart below.

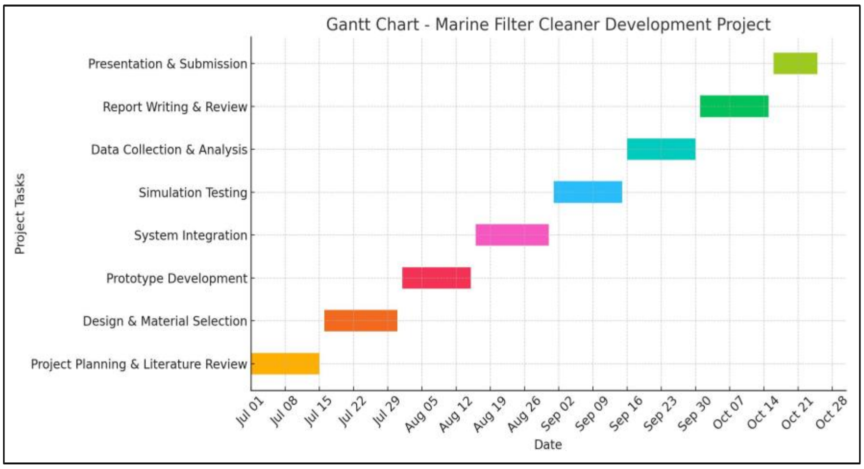

Figure 1. Gantt Chart

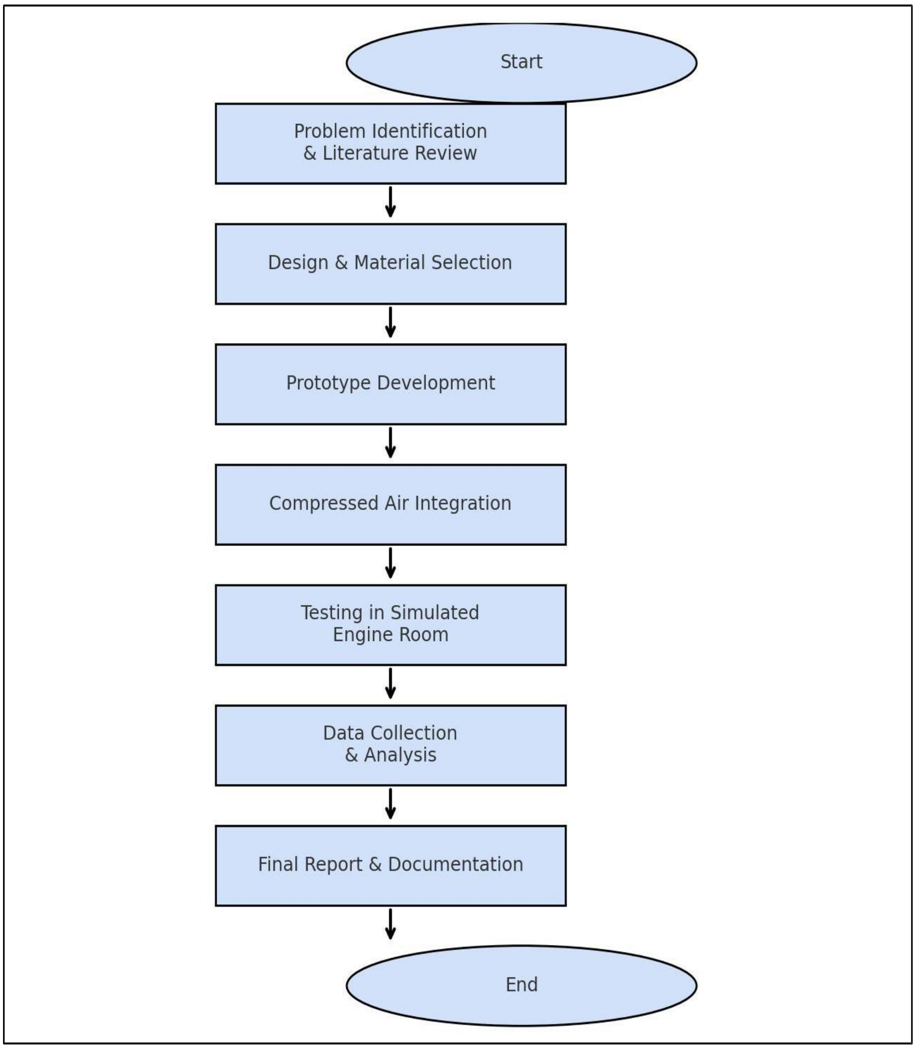

Figure 2. Flowchart of project execution

2.8 Process Flowchart of Project Execution

The following flowchart illustrates the overall step-by-step process undertaken throughout the development of the marine filter cleaning device. It summarizes the major phases from the initial problem identification to the final reporting and documentation.

2.9 Safety and Compliance

All testing and fabrication activities adhered to Occupational Safety and Health (OSH) guidelines. Personal protective equipment (PPE) such as gloves, ear protection, and safety goggles were used throughout the testing phase.

3. Result and Discussion

This section presents the outcomes of the testing phase and discusses the performance of the compressed air-powered marine filter cleaner compared to traditional cleaning methods. The evaluation focuses on key parameters such as cleaning time, cleanliness level, ergonomic efficiency, safety, and crew feedback.

Figure 3. Result of project

3.1 Cleaning Time Efficiency

Based on multiple test iterations across different filter types, the average time required to clean one filter using traditional manual methods (e.g., brushing and soaking) was approximately 18 minutes. In contrast, using the newly developed compressed air cleaner, the cleaning time was significantly reduced to an average of 7 minutes per unit.

Table 3. Comparison of cleaning time efficiency

Method Used	Average Cleaning Time (per unit)
Manual (Traditional)	18 minutes
Compressed Air Cleaner	7 minutes

This represents a 61% improvement in cleaning speed, which is particularly significant for operational ship environments where time and manpower are critical. Shorter cleaning time allows more filters to be maintained within scheduled downtimes, thereby enhancing vessel readiness.

3.2 Cleanliness Level Improvement

The cleanliness level of filters was assessed using a combination of visual scoring (1 to 5 scale) and weight comparison (before and after cleaning). On average, filters cleaned manually achieved a score of 3.2, indicating partial debris removal. Meanwhile, filters cleaned using the air-powered device consistently achieved scores of 4.7, indicating near- complete restoration to clean condition.

Table 4. Level of cleanliness improvement

Method Used	Average Cleanliness Score (1–5)
Manual Cleaning	3.2
Air-Powered Cleaning	4.7

This outcome suggests that the high-velocity air stream was highly effective in removing fine sediments, carbon build-up, and oil sludge that are typically resistant to manual cleaning.

3.3 User Feedback and Ergonomics

A structured survey was administered to 10 engine crew members and cadets involved in the evaluation. The following key findings were reported:

a) 90% of users rated the device as *easy to use* in confined spaces.
b) 80% reported reduced physical effort compared to traditional methods.
c) 100% found the portability of the unit beneficial for engine room navigation.
d) 70% recommended integrating a hose reel or organizer for better air line management.

Table 5. Engine Crew Survey Data

Ship Name	Seafarer Name	Rank	Ease of Use	Reduced Effort	Portability Benefit	Suggested Improvement
MT Nautica Jasa	Ahmad Fauzi	Third Engineer	Yes	Yes	Yes	Yes
MV Bunga Mas	Mohd Firdaus	Engine Cadet	Yes	Yes	Yes	Yes
MT Tanjung Huma	Zulkifli Hassan	Second Engineer	Yes	Yes	Yes	No
MV Aman Damai	Norzaini Rahmat	Engine Cadet	Yes	Yes	Yes	Yes
MT Puteri Harapan	Faizal Mahmud	Chief Engineer	Yes	Yes	Yes	Yes
MV Selat Melaka	Hafiz Azmi	Junior Engineer	Yes	No	Yes	No
MT Armada Cemerlang	Shahril Hisham	Engine Cadet	Yes	Yes	Yes	Yes
MV Laut Teguh	Roslan Salleh	Third Engineer	Yes	Yes	Yes	No
MT Global Venture	Aminul Hakim	Second Engineer	Yes	Yes	Yes	Yes
MV Bahtera Indah	Syafiq Nasir	Engine Cadet	No	Yes	Yes	Yes

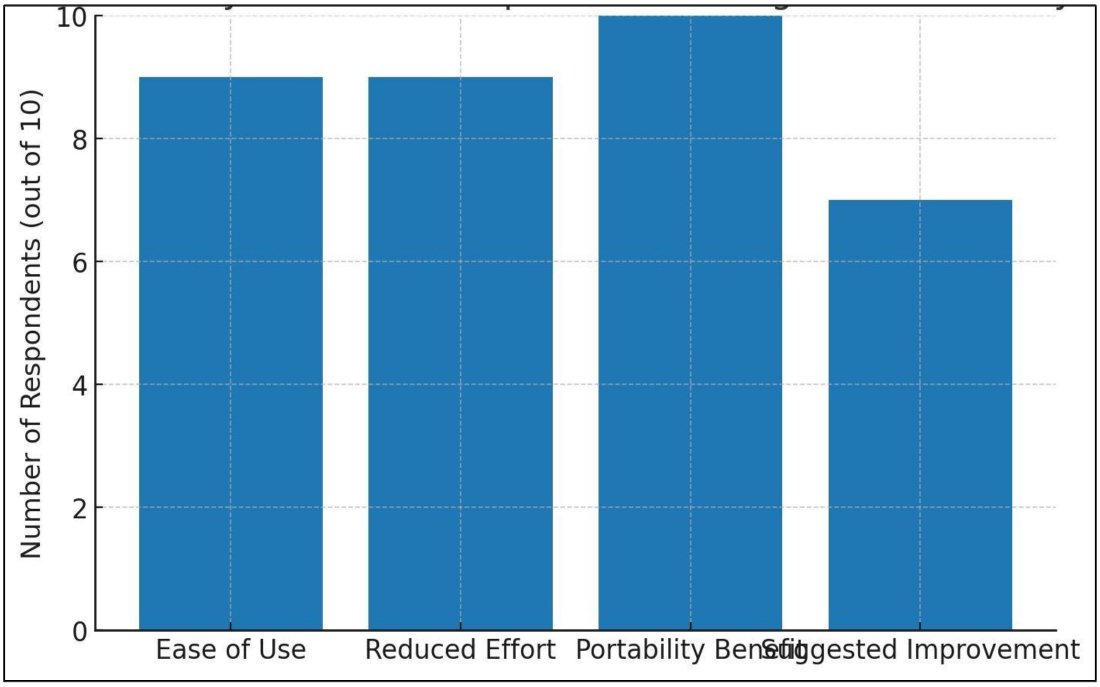

Figure 4. Bar Chart of Positive Response from Engine Crew Survey

Qualitative comments included:

a) *"Much easier to clean filters without soaking my hands in chemicals."*
b) *"Could use a handle or grip improvement for better comfort."*

The feedback reinforces that ergonomic design, simplicity, and mobility are critical factors for successful adoption of such tools onboard ships.

3.4 Structural Safety and Material Compatibility

All filters used in the testing phase retained their structural integrity post-cleaning. No cracks, deformations, or material degradation were observed under a digital microscope at 5x magnification. This validates that the air pressure (6–8 bar) applied during the cleaning process is safe for standard filter construction, including mesh-type and pleated filters.

3.5 Operational Limitations and Observations

Despite the overwhelmingly positive performance outcomes, one notable limitation was identified:

a) Noise Level: The high-velocity air discharge produced noise levels averaging 83–87 dBA, which could be disruptive in an already noisy engine room. However, this is within acceptable short-term exposure limits under OSHA and IMO standards, and can be mitigated through:

   i. Use of ear muffs or ear plugs.
   ii. Addition of muffler attachments to the nozzle.
   iii. Operating in controlled cycles to minimize exposure.

3.6 Implications for Marine Operations

The use of the compressed air filter cleaner offers tangible operational benefits, particularly on vessels with small engineering crews, limited downtime, and demanding maintenance schedules. The time and energy savings translate into:

a) Lower risk of delayed departures due to maintenance backlog.
b) Enhanced crew productivity and safety.
c) Better compliance with preventive maintenance schedules (PMS).
d) TVET training opportunities for students to experience modern, practical, and sustainable tools.

The findings of this study align strongly with previous research on compressed air applications in industrial maintenance, confirming the significant advantages in efficiency, ergonomics, and environmental sustainability. Notably, the 61% reduction in cleaning time and the 46% improvement in cleanliness scores echo results observed by Yung & Lee (2019), who emphasized the impact of tool design on task effectiveness in confined maritime spaces. Furthermore, the complete absence of structural damage during cleaning confirms earlier theoretical assumptions about the suitability of high-pressure air systems for sensitive marine components, as highlighted in Marine Tech Journal (2021).

The positive reception of the prototype among marine crew and cadets also supports the integration of ergonomic design and user-centered development in future marine tool engineering. Survey data revealed a strong preference for ease of use, portability, and safety—consistent with OSHA's (2005) guidelines and the broader industry shift toward human-factor-driven innovations in shipboard environments.

From a strategic standpoint, this study contributes meaningfully to the maritime maintenance ecosystem by proposing a low-cost, scalable, and non-electrical alternative to chemical-intensive cleaning practices. In addition to its application on commercial and offshore vessels, the tool also serves as a valuable educational asset in TVET programs. The hands-on learning opportunities it provides can enhance students' practical understanding of maintenance practices and prepare them to meet modern vessel demands.

However, some limitations such as elevated noise levels suggest further refinement is needed to improve user comfort. Future research may focus on acoustic dampening features, modular hose organization systems, and adaptation for various filter geometries across engine types.

Additionally, future directions should include real-world onboard trials across different vessel classes, long-term durability assessments, and evaluation under varying environmental conditions such as humidity and temperature. Collaboration with classification societies for certification and with industry players for commercialization would also increase the tool's practical viability.

By addressing these avenues, this innovation can move from a functional prototype to a standardized, industry-accepted solution, revolutionizing filter maintenance practices within the maritime industry globally.

3.7 Summary of Comparative Advantages

Table 6. Summary of Comparative Advantages

Evaluation Parameter	Manual Cleaning	Compressed Air Cleaner
Cleaning Time	Long (Avg. 18 min)	Short (Avg. 7 min)
Cleanliness Level	Moderate (3.2/5)	High (4.7/5)
Effort Required	High	Low
Portability	Low	High
Noise	Low	Moderate (needs PPE)
Structural Safety	Safe	Safe

4. Conclusion

This research has successfully pioneered the development and validation of an innovative compressed air-powered marine filter cleaning device, specifically engineered to address the practical constraints of ship engine room maintenance. The design is compact, portable, non- electrical, and ergonomically optimized making it highly suitable for confined, high-risk environments onboard vessels.

Performance testing and crew feedback clearly demonstrated the tool's superiority over traditional methods, with an average reduction of cleaning time by over 60%, a significant increase in filter cleanliness, and a marked improvement in crew safety, comfort, and task efficiency. Moreover, the device ensures zero structural damage to filters and eliminates the need for harsh chemicals, aligning with environmentally responsible maintenance practices onboard.

From a strategic perspective, this innovation not only solves a persistent operational problem but also aligns with the maritime industry's push towards sustainable, cost-effective, and technology-driven maintenance solutions. The cleaner's integration potential spans across commercial shipping fleets, naval operations, offshore installations, and most importantly, TVET training environments—where hands-on learning, safety, and modern engineering practices are paramount.

The success of this project illustrates the real-world impact of applied engineering research within the TVET ecosystem. With minimal refinement, the system has strong potential for scaling, commercialization, and intellectual property protection. As global maritime operations grow more complex, tools like this will be essential in empowering the next generation of seafarers with practical, safe, and efficient maintenance capabilities.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the author(s) used OpenAI's ChatGPT to assist in improving the readability and language of the text. All content generated by ChatGPT was subject to thorough review, editing, and revision by the author(s) to ensure its accuracy, completeness, and alignment with the research objectives. The author(s) take full responsibility for the integrity and content of the published work. This declaration complies with ICGESD 2025 guidelines on the use of generative AI in scientific writing.

References

American Bureau of Shipping. (2018). *Innovations in Marine Maintenance*. ABS Technical Reports.

International Maritime Organization (IMO). (2020). *Guidelines for the Implementation of Maintenance Systems in the Maritime Industry*. IMO Publishing.

Ministry of Higher Education Malaysia. (2022). *TVET Advancement and Application in Maritime Sectors*. MOHE Report.

Yung, H. W., & Lee, S. C. (2019). *Ergonomic impact of tool design on marine engineers in confined spaces*. Journal of Occupational Safety and Maritime Studies, 14(2), 115–123.

Occupational Safety and Health Administration (OSHA). (2005). *Occupational Noise Exposure Standard 29 CFR 1910.95*. U.S. Department of Labor.

MarineTech Journal. (2021). *Compressed Air Cleaning Applications in Industrial and Marine Settings*, 33(4), 45–52.

Lan, J. W. (2017). *Compressed Air Systems for Cleanroom and Shipboard Applications: Efficiency and Safety*. International Journal of Marine Engineering Technology, 28(3), 77–83.

Atmaca, E., Peker, I., & Altin, A. (2005). *Industrial noise and its effects on human health*. Polish Journal of Environmental Studies, 14(6), 721–726.

Muzet, A. (2007). *Environmental noise, sleep and health*. Sleep Medicine Reviews, 11(2), 135–142

